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Construction Stage Analysis of RCC Frames

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ABSTRACT

While analyzing a multistorey building frame, conventionally all the probable loads are applied after modeling the entire building frame. But in practice the frame is constructed in various stages. Accordingly, the stability of frame varies at every construction stage. Even during construction freshly placed concrete floor is supported by previously cast floor by formwork. Thus, the loads assumed in conventional analysis will vary in transient situation. Obviously, results obtained by the traditional analysis will be unsuitable. Therefore, the frame should be analyzed at every construction stage taking into account variation in loads. The phenomenon known as Construction Stage Analysis considers these uncertainties precisely. This paper analyzes several numbers of multistorey reinforced concrete building frames of different bay width and length, storey height and number of stories using STAADpro, followed by the construction stage analysis of each model. Also all full frame models are analyzed for earthquake forces in Zone - II (IS 1893 : 2002). Finally, a comparative study of Axial forces, Bending moments, Shear forces and Twisting moments was done at every storey for full frame model (without earthquake forces) and construction stage model (without earthquake forces).

Keywords: *Construction Stage Analysis, Construction Sequence Analysis, Construction Loads, Sequential Gravity Loads.*

1. INTRODUCTION

Structural Analysis of multi-storey buildings is very much known and old area of research field. Evaluation of various uncertainties are always recognized and investigated every new day. Since early 1950s (Neilsen 1952; Grundy and Kabaila 1963; Agarwal and Gardner 1974; Noble 1975; Fattal 1983; Sbarounis 1984; Lew 1985; Liu et al. 1986), the uncertainty of excess loads on slabs due to formworks and various construction logistics during construction is being investigated. It was found that during construction slabs carry loads in excess of service life loads. The problem was well researched for the loads of formwork and imposed loads during construction. Even due to the time dependent behavior of cement concrete structures the conventional analysis approach does not gives reliable results. To tackle with the above mentioned uncertainties, various approaches were made. These uncertainties generally follow the sequence of construction process of the building. Therefore, while analyzing the buildings considering the sequential application of loads and construction process, the instability of incomplete structure created another problem. This phenomenon is still boom amongst many researches since 1970s. In 1978, S.C Chakrabarti, G.C. Nayak and S.K. Agarwala studied the effect of self weight only during construction process of buildings. Choi and Kim (1985); Saffarini and Wilson (1983) also dealt with the same problem independently but they considered the effect of differential column shortening under dead loads only and unfortunately paid less attention to the responses of various forces due to excess construction loads and instability of incomplete structures.

The aforementioned uncertainties were amongst the reasons advocated by an ASCE member Kenneth L. Carper (1987) for most of the structural failures during construction. These uncertainties increased the computational efforts for the analysis of multistorey buildings. Choi and Kim (1985) used the

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"One floor at a time" analysis approach for solving the problem. But it was beyond the human computational efforts. In 1992 Chang-Koon Choi, Hye-Kyo Chung, Dong-Guen Lee, and E. L. Wilson proposed a simplified analysis approach known as "*Correction Factor Method (CFM)"* considering only dead loads.

With the above discussion it is clear that very less attention has been paid on the effect of instability of incomplete structure and the variation of loads during construction. Therefore, this paper deals with the responses of various forces in terms of axial forces, bending moments, shear forces and twisting moments induced in the members of a RC building. Figure 2 clearly differentiates between the conventional analysis and Construction Stage Analysis of multistorey frames.

2. RESEARCH METHODOLOGY

In this paper several models of G+5 and G+7 RC buildings frames with 4 bays along length and width are analyzed using STAAD*pro*. Various stiffness governing factors such as bay width/length, storey height, etc. are decided as basic parameters. Six frames of five storied and seven storied RC buildings of bay width/length 4m, 5m and 6m and storey height 3m were modeled and analyzed with conventional method and by Construction Stage Analysis. Then three frames of five storied RC building of storey height 4m and bay width/length 4m, 5m, and 6m were also analyzed by both the methods. These nine models were used for the comparison of responses of various forces in terms of axial forces, bending moments, shear forces and twisting moments. Figure 1 shows the typical floor plan of the models.

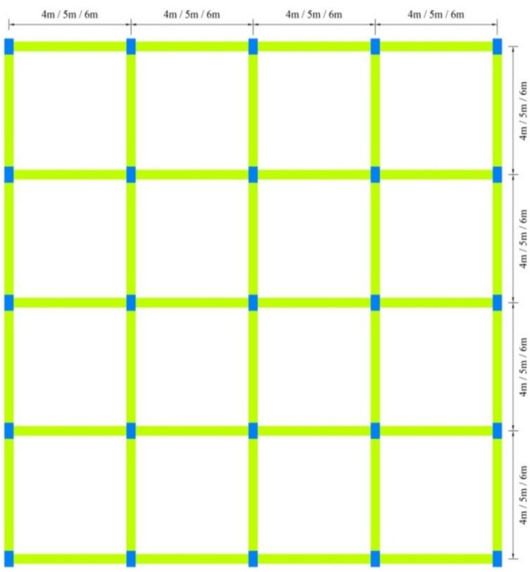

Figure 1 Typical Floor Plan

The summary of member sizes for G+5 and G+7 with storey height of 3m and 4m is shown in Table 1 below -

Table 1 Summary of Member Sizes

Bay Width/Length	4 m	5 m	6 m
Column Size (m x m)	0.23 x 0.60	0.30 x 0.60	0.30 x 0.75
Beam Size (m x m)	0.23 x 0.45	0.30 x 0.60	0.30 x 0.60
Slab Thickness (mm)	150	150	200

2.1 Construction Stage Analysis

Consider a typical floor (say *C*) of a frame shown in figure 2(b). Assuming the building is constructed one floor at a time, the *C* floor is constructed on the top of the frame that was completed so far [i.e., up to *(C - 1)* floor]. The slab of *(C-1)* floor supports the selfweight of freshly poured *C* floor slab by the formwork in addition to its own selfweight. Also the construction live load on *C* floor equal to the inspection live load on *(C-1)* floor will be transferred to the slab of *(C-1)* floor. Figure 2(b) clearly illustrates how the loads transfers on the frame in construction stage analysis.

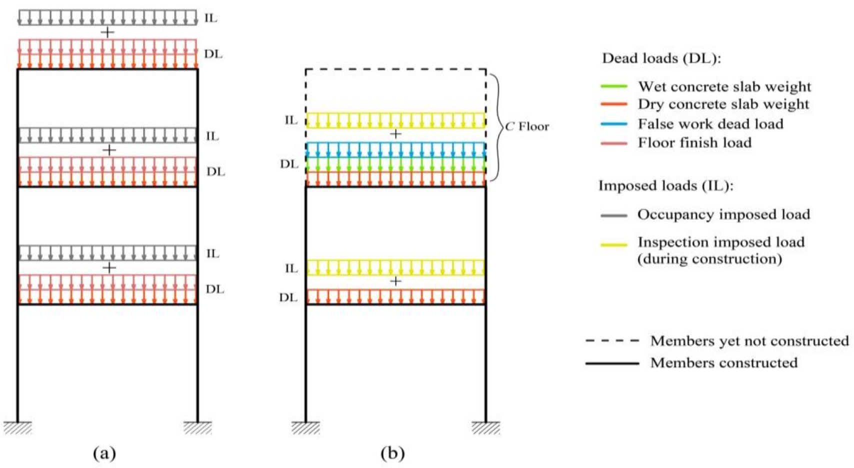

Figure 2 (a) Conventional Analysis; (b) Construction Stage Analysis.

2.1.1 Loadings

Load Cases

1) Dead Loads

i) Selfweight of columns and beams;
ii) Selfweight of dry concrete slab (weight density = 25 kN/m^3);
iii) Selfweight of wet concrete slab (freshly poured) [weight density = 26 KN/m^3 (refer IS 14687 : 1999)];
iv) False work dead load [500 N/m^2 (refer IS 14687 : 1999)].

2) Imposed Loads

i) Inspection live load on *Constructed* floor slab [750 N/m^2 (refer IS 14687 : 1999)]
ii) Construction live load on floor slab being constructed [assumed adequate to be equal to inspection live load i.e. 750 N/m^2 (refer IS 14687 : 1999)]

Load Combinations

1) 1.5 times dead loads and imposed loads [i.e. 1.5(DL+LL)].

2.2 Conventional Analysis

As illustrated in figure 3.2(a), all the probable loads were applied after modeling the entire frame.

2.2.1 Loadings

Without Earthquake Forces

Load Cases

1) *Dead Loads including floor finish*
2) *Imposed Loads:* 2.5 KN/m^2 (refer IS 875 : 1987)].

Load Combinations

1) 1.5 times dead loads and imposed loads [i.e. 1.5(DL+LL)].

2.2.2. With Earthquake Forces

Earthquake Loads and different load combinations as per I.S. 1893-2002 Part II in Earthquake Zone II considering ductile detailing.

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3. COMPARISON

The results obtained were compared with construction stage model. Then all full frame models were analyzed for earthquake forces in Zone – II in accordance with IS 1893 : 2002. The location for all the buildings was assumed in Aurangabad city of Maharashtra in the territory of India. Note that earthquake forces were not considered for analyzing the construction stage models. The results of construction stage model were compared conventional analysis considering earthquake forces for knowing the significance of any one of them. Here only first storey comparison graphs of G+5 structures are shown.

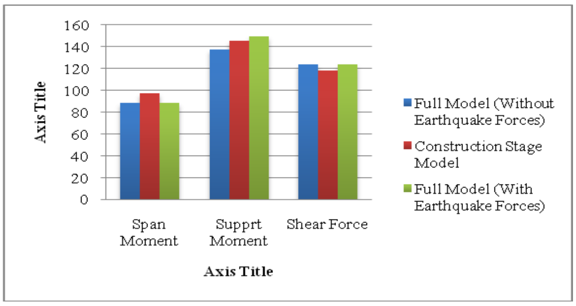

Figure 3 Responses in Edge Beams at 1st Storey of G+5 (3m Storey height) RC Building

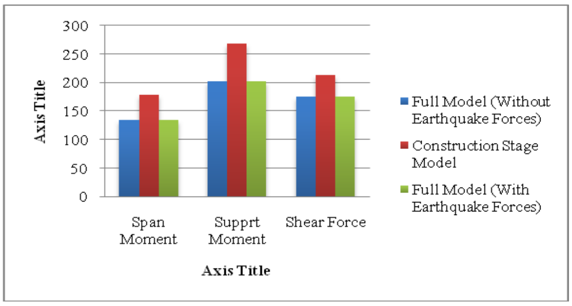

Figure 4 Responses in Interior Beams at 1st Storey of G+5 (3m Storey height) RC Building

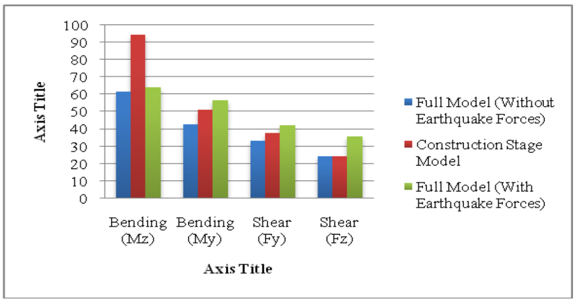

Figure 5 Responses in Corner Columns at 1st Storey of G+5 (3m Storey height) RC Building

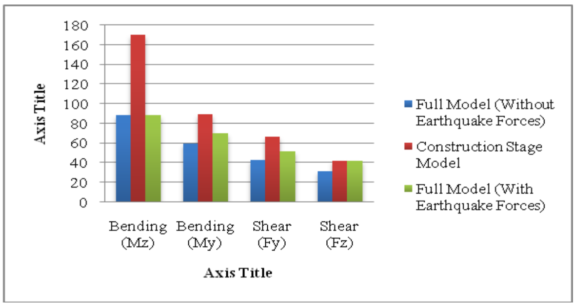

Figure 6 Responses in Edge Columns at 1st Storey of G+5 (3m Storey height) RC Building

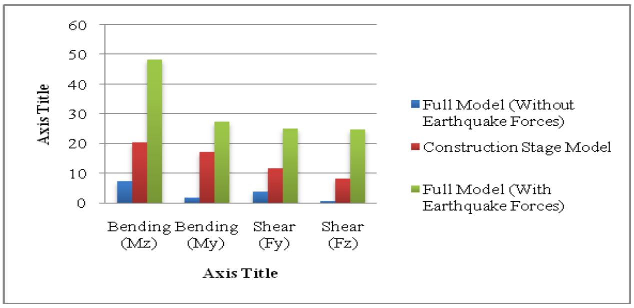

Figure 7 Responses in Interior Columns at 1st Storey of G+5 (3m Storey height) RC Building

Comparison graphs at every storey of G+5 as well as G+7 RC structures are found to be almost similar.

3.1 Discussions

Beams

1) Edge beams are found to be critical for all the responses except twisting moment and span moment if analyzed conventionally considering earthquake forces.
2) Whereas, interior beams are always critical during construction. Therefore, construction stage analysis is most suitable.

Columns

1) Corner columns are found to be critical during earthquake and not during construction.
2) Whereas edge columns are critical if analyzed by construction stage analysis.
3) For interior columns all the responses are governed by earthquake forces.

There is no effect of number of stories or storey height on the responses of the external forces.

4. CONCLUSION

Based on the broad investigations and comparisons following conclusions were drawn:

1) No significant advantage in case of column design is considered but there is a scope to check the columns considering the primary rotations at every stage.

2) Interior beams are always critical in construction stage as far as design moments are considered.

3) Construction stage analysis is proved critical even if earthquake forces during the construction are not considered.

Hence, Construction stage analysis considering earthquake forces will provide more reliable results and recommended in usual practice.

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